**TESTING THE SUSTAINABILITY OF CROATIAN MILITARY FORCES: SYSTEM DYNAMICS APPROACH**

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**Abstract**

In line with the global trends, Croatian military is going through a transformation, but is currently being stifled by a long recession and negative demographic trends. The purpose of this article is to outline the possibilities for the usage of system dynamics models in testing the sustainability of Croatian military forces according to the size and composition. The main focus of the article is on the demographic trends and their implications on the CMF. After a brief exposition of the research done in this field so far, two models are developed in the article – a demographic model and a military recruitment model. The models were carefully tested using validation tests suitable for system dynamics modelling. After the validation, the models were merged into one integral system dynamics model of CMF. Three experiments were conducted based on the different fertility values, and impact of demographic trends, which emerge from the different fertility levels, was tested. The results of the simulation, based on the use of the demographic data from the Census of 2011, as well as estimates for the data which was not accessible at the time, suggest that the Croatian military could have trouble meeting its demands for recruits in the next 20-30 years. Additional implications of the current demographic trends on the sustainability of the CMF are discussed in the end. Since the basic inputs for any organization are labor and capital, the problem is addressed from two complementary perspectives: a demographic perspective and a financial one.

**Keywords:** S*ystem dynamics, Military forces, Demography, Fertility*

## 1. Introduction

During the last thirty years, there were four major events that changed the perception of what constitutes a modern army. The breakdown of the Soviet Union marked the end of the Cold War, as well as the change of focus from maintaining a large military force for the purpose of deterrence to the two-theatre approach to warfare. [23] The events of 9/11 and the subsequent wars in Afghanistan and Iraq brought attention to the requirements of asymmetric and urban warfare, in addition to highlighting international terrorism as a growing threat to global security. The rapid technological advancement in the fields of electronics and communication opened new possibilities and challenges to defense doctrines by introducing robotics and ‘intelligent’ weaponry to the battlefield, while the global economic crisis of 2007. introduced sterner budgetary constraints and brought the cost-effectiveness of military programs back in the eye of the public [24].

To adapt to the needs of modern warfare, some of the world’s military organizations are undergoing modernization and significant restructuring. Since military organizations are often large and complex systems, such changes pose a challenge for most countries because of the significant effect the military has on a social and economic level due to the size of its budget, workforce and other consequences that stem from these choices. The main thesis of this paper is that system dynamics can be used as a tool to provide an overview of these effects and to determine the viability and long term sustainability of planned organizational transitions.

The purpose of this paper is to determine the possibilities of using system dynamics as a tool for evaluating the sustainability of a predetermined combination of manpower, equipment, training and other aspects that constitute a military force.

## 2. Military applications in system dynamics

The primary application for system dynamics models is to facilitate support for decision-making in regards to complex environments. Due to the nature of both the organizational and logistical aspects of the military, as well as warfare itself, there is a continued interest in the military application of such models since that support could bring a decisive edge in military situations.

A major contributor to the field is considered to be R.G. Coyle, who first explored the potential of system dynamics for providing an overall view of problems and the dynamics of military operations, by publishing a model of a hypothetical World War III. [4] From then on, system dynamics was applied to most aspects of defense and military related issues. A significant amount of research was done in the field of supply management simulations, whether it was modelling military equipment support [5] weapon maintenance supply systems [10].

System dynamics was successfully applied in other related areas. In strategic project management, system dynamics models have demonstrated the ability to improve significantly the quality and performance of management on complex projects [15]. In combination with discrete event simulations, system dynamics was successfully utilized in developing frameworks for modelling combat situations with the use of Lanchester Laws [2]. It was also used to test whether some of the same factors influence both violent conflicts and sustainable development [28], as well as in creating a model to evaluate counter-insurgency policies [1].

Manpower planning models were used to see how recruitment and attrition affected the costs of organizations with different hierarchies [11], and training force sustainment models were successful in illustrating the possibility of creating a bullwhip effect even in situations related to human resource management [27].

Although system dynamics research is being done in Croatia for the last couple of decades, a very small part of it is applied to military issues. Research was done on the demographic sustainability of the Croatian military, and a system dynamics model was created based on its previous organizational structure [26], but due to the abandonment of conscription in favor of creating a smaller, professional military force in 2008., it is no longer applicable to the current situation.

Therefore, the decision was made to create a new manpower planning model of the Croatian Armed Forces with the emphasis on the demographic sustainability to determine whether the new organization has the potential for long-term sustainability and to highlight the issues that could come up due to the specific circumstances in the country and of the model.

## 3. Understanding the dynamics of sustainability of Croatian Armed Forces

There are several approaches for determining the sustainability for complex organizations such as the military. The criteria for differentiation are the definition of sustainability and the benchmarks used in the research, as well as the factors used to determine whether the observed organization is sustainable. In this case, we focused our efforts into modelling and observing whether a change in the dominant demographic trends (i.e. low fertility) will affect the ability of the Croatian military to fill its ranks appropriately, based on current laws and procedures that govern the recruitment process. The data on the demographic trends obtained through experimentation with the model will also be used in the discussion to suggest other mechanisms in which they can affect the long-term sustainability of the Croatian military force.

In order to achieve this, two models were created: a demographic model and a recruitment model. Both models were developed using the “step-by-step” approach [22], as well as tested using the dimensional consistency test, the extreme conditions test and the behavior sensibility test. Although the results of the validation tests are not shown in this article for reasons of brevity, they were conducted during the building process to assure the consistency of the results, as well as the reliability of the model.

## The demographic model

The demographic model was designed as a cohort-component model divided into three branches: the male branch, the female branch and the immigration branch. The female branch is divided further into six cohorts: 0 to 14 years old, 15 to 17 years old, 18 to 27 years old, 28 to 49 years old, 50 years old to RA (retirement age), and the female RA and older group. The male branch is divided into six age groups as well: 0 to 17 years old, 18 to 27 years old, 28 to 34 years old, 35 to 44 years old, 45 years old to RA, and the male RA and older group.

The age limitations for the cohorts were chosen to enable the observation of the three variables derived from different combinations of said cohorts: the number of female citizens in fertile age, the number of citizens that are (by the criteria of age) eligible to apply for military service, as well as the size of the workforce. Each cohort has a single inflow (births or maturation) and three outflows (maturation, emigration and dying) which are determined mostly by external factors, such as fertility and mortality rates, as well as the estimated rate of emigration for each cohort. The only exceptions are the “Female RA and older” and “Male RA and older” variables, where the maturation outflow is not necessary.

The use of low-resolution cohort-component analysis and actual population data for Croatia in the model, as well as the need to preserve the age structure of the population throughout the duration of the simulation, required some modifications to the otherwise straightforward maturation or ageing mechanism.

The value of the maturation variable depends on three other variables: the maturation lookup, the delay, and the specific mortality rate for the cohort. The maturation lookup contains the numbers of people that already belong to the observed cohort and that will age beyond the upper limit for the cohort each year until the first generation of the newcomers (people that advanced in age from the previous cohort) ages enough to pass the upper limit for said cohort. The delay variable makes certain that the number of people entering the cohort also exits the cohort after the appropriate length of time. The value of the delay variable is adjusted for the appropriate specific mortality rate, taking into account the time it took for the generation to pass through the cohort, as well as emigration, in the maturation equation for the cohort.

Due to legal limitations of applying for citizenship [17] and/or military service [19], its annual rate, as well as other practical limitations, immigration is represented by a simple population model. The number of female immigrants, however, does affect the rate of births in the other branches, and its estimated proportion is included into “the number of female citizens in fertile age” variable.

## The recruitment model

The models are connected through the “Recruitment pool” variable, which estimates the number of people eligible for military service, and considers that male and female members of the population have equal interest in serving – which currently is not empirically correct, but it can be considered as a best case scenario. Since military service is voluntary in Croatia, the constant “ACCEPTABILITY OF MILITARY SERVICE” has been added to account for the proportion of people from that age group which would consider joining. A portion of the pool determined by the “SHARE READY TO APPLY LOOKUP” goes through the application process and into the “Applied” stock variable. From there, a number of individuals determined by the “PLANNED TESTING LOOKUP” is being sent to testing, while others are sent to the “On hold T” stock variable. A fixed percentage of the “Applied” number is considered to have given up and is removed from the stock using the “gave up 1” outflow.

Candidates that are sent on hold have priority in the next testing cycle, and when there are any in the “On hold T” stock variable, they are sent through the “later testing” outflow to the “Tested” stock variable, and as many of them as the “PLANNED TESTING LOOKUP” allows. If the “PLANNED TESTING LOOKUP” allows for more people than are currently available in the “On hold T” stock variable, people are sent through the “testing” outflow directly to the “Tested” stock variable.

All candidates that went through the testing procedure are represented in the “Tested” stock variable. From there, a number of the candidates smaller or equal to the predetermined limit that successfully passes the tests are directed into service, while others are put on hold until the next cycle.

A person going through Voluntary military service or “VMT” can either give up during training, graduate or graduate as a military specialist. People that give up exit the system completely; people that graduate into military specialists have been employed due to certain special skills, and are sent to their respective posts immediately after successfully completing the “VMT”, while others are sent to the “Went through VMT” stock variable. From that point they can exit the system through ageing, or by seeking employment in the military.

According to Croatian law [18], a commissioned soldier can sign a contract with the military three times: the first contract lasts for three years, the second for five years, and the third one for six years. After the signing of the second contract, soldiers with an exemplary record and an adequate level of education may be considered for advancement into non-commissioned officers. The same criteria apply for the advancement into the ranks of commissioned officers, except that the chosen candidates for the position of commissioned officers have to go through one year of additional training.

There are several reasons to why the values of outflows from the stock variables 3 years, 5 years, 6 years, NCO-s, Commissioned officers, and Military specialists are determined by values stored in lookups, and not by the feedback loops in the model itself. The first one is that not enough data about the composition of the Croatian military forces is publicly available to reliably develop what would in a sense be a military restructuring model. The second reason is that the decisions on the number of soldiers to be recruited, discharged or retired can be made by the Croatian Parliament, based on the suggestion from the Croatian Government as necessary [19], and are as such subject to a number of discrete political, military and economic circumstances.

The model also calculates several key indicators that do not have an essential role in the functioning of the model, but that illustrate some side issues that provide valuable context for the results. The equations for these indicators are given below:

(1) workforce = Total population-Female age 0 to 14-Female age 15 to 17-Female RA and older-Male age 0 to 17-Male RA and older

(2) share of workforce in total population = workforce/Total population

(3) Total reserves = contractual reserves + mobilizational reserves



Figure 1. The diagram of the demographic model



Figure 2. The diagram of the recruitment model

## 4. Simulation results analysis

## 4.1. Experiment design

The main focus of this paper is on the demographic trends in Croatia over the next 50 years and their impact on the Croatian Armed Forces, especially on the influence of the changes in the total fertility rate, which is widely recognized as a key aspect of the population decline in Croatia over the last several decades. The experiment was designed in order to determine whether the proposed demographic trends will be able to sustain the needs of the military for manpower under the provided conditions and to find the variables that have the greatest influence on its outcome.

To that effect, three scenarios were chosen to monitor the changes in the size and structure of the total population in Croatia during the observed period: the low-fertility Scenario 1, the medium fertility Scenario 2, and the high fertility Scenario 3. These scenarios were developed by Gelo, Akrap and Čipin [12], and the fertility values are presented in Table 1.

The starting values for the stock variables representing different age groups of both the male and female population were sourced from the results of the Census of 2011. [8], and the mortality rates for these groups were calculated as weighted averages of the mortality rates for the appropriate ages published in the Statistical Yearbook of 2012. [7]. The maturation rates found in the lookups of the demographic model compensate for the size of the age groups for the purpose of maintaining the appropriate age structure by using pre-calculated values for the maturation rates. These rates are used until enough time has passed that the first generation of people that entered a certain age group matured enough to exit that same group.

The starting values for immigration and emigration rates were calculated as averages of the values published by the Croatian Bureau of Statistics for the 2008. to 2012. period [6], but the values concerning future immigration are estimations designed to negate the effect of the proposed emigration rates on the total population. This decision was made to simplify the model because there is no current research available to the authors that would enable the creation of a more refined migration model.

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| --- | --- | --- | --- |
| Period | Scenario 1 | Scenario 2 | Scenario 3 |
| 2010-2014 | 1,4 | 1,48 | 1,6 |
| 2015-2019 | 1,35 | 1,42 | 1,65 |
| 2020-2024 | 1,3 | 1,38 | 1,75 |
| 2025-2029 | 1,25 | 1,33 | 1,85 |
| 2030-2034 | 1,2 | 1,3 | 1,95 |
| 2035-2039 | 1,15 | 1,25 | 2,05 |
| 2040-2044 | 1,1 | 1,3 | 2,1 |
| 2045-2049 | 1,1 | 1,35 | 2,1 |
| 2050-2054 | 1,1 | 1,4 | 2,1 |
| 2055-2059 | 1,1 | 1,5 | 2,1 |
| 2060-2064 | 1,1 | 1,55 | 2,1 |

Table 1. The predicted total fertility rates for the low, medium and high fertility scenarios for the observed period. [6]

A slight problem with the experiment design arose concerning the availability and existence of official data and/or research related to the military part of the model, especially for some lookups and variables. Where it was possible, official records and peer reviewed papers were used as sources, but some of the values either came from less reliable sources (e.g. newspaper articles) or are conjecture based on circumstantial information or author’s estimates.

The “ACCEPTABILITY OF MILITARY SERVICE LOOKUP” is treated as an exogenous constant, estimated at the value of 0.45, meaning that 45% of the population of the recruitment pool finds the possibility of military service acceptable. The estimation is based on the research done by Matika and Ogorec [16], which shows that 27.7% of respondents would like to find employment in the military, and that 61.5% would seek employment in the military only if they could not find it elsewhere. The share of the second group in the total population of the recruitment pool is adjusted by the rate of unemployment for that age group [3].

The “SHARE READY TO APPLY LOOKUP” is also treated as an exogenous constant, valued at 0.01. This estimation is based on unconfirmed reports that around 6600 people applied for voluntary military training in the period between 2008. and 2011., which is around 2200 people per year, or approximately 1% of the recruitment pool [13]. The value of the “PLANNED TESTING LOOKUP” is an estimate based on the media reports regarding waiting periods and the assumed number of applicants [9].

The value of the “PLANNED DIRECTION INTO SERVICE LOOKUP” is based on the number of applicants currently being admitted for voluntary military training on a yearly basis [18]. The value of the “GIVE UP” lookups is an estimation of the share of people that did not succeed in reaching the next phase of the recruitment process for any reason, and it is more or less a free estimate due to the lack of any official data to that regard.

The values for the promotion, graduation, retirement and dismissal lookups were calculated based on the Plan for Admission into Active Military Service for the year 2014 [25] and the planned ratio of commissioned officers, NCO’s and soldiers in the active service according to the Strategic Defense Overview [18].

## 4.2. Population dynamics simulation results

The results of the population dynamics simulation predict a significant decline in the population in all three scenarios due to low total fertility rates, as well as the low inflow of immigrants. However, there is a significant difference in the total population at the end of the observed period due to the sizeable difference in the total fertility rate between the pessimistic Scenario 1, and the optimistic Scenario 3.



Figure 3: A graph illustrating the changes in the size of the total population based on the proposed scenarios over the simulated period.

Because members of the military are predominantly male, the population dynamics of different male age groups are shown to illustrate several important implications of the results of the proposed demographic trends. The first important implication is that, although it has an immediate effect on the size of the total population, any change in the total fertility rate takes 18 years to affect the size of the workforce or the pool for military recruitment, as seen in Figure 4.

The second important implication is that population of the “Male age 18 to 27“ cohort, which forms the base for military recruitment, experiences a significant reduction in every one of the proposed scenarios. Although the population stabilizes around 200000 members in Scenario 3, its steady decline in scenarios 1 and 2 lowers the expected population size to about 100000 – a third of the population size at the beginning of the simulation.

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Figure 4: Graphical reprezentations of the simulation results for the male population aged 0 to 17 and 18 to 27 throughout the duration of the simulation in all three scenarios.

In the population of males age 28 to 34 and 35 to 44, a steady decline is seen throughout the entire observed period in every scenario except in scenario 3, in which stabilization is observed after the first generation of people born in the model enters the respective age groups. By then, however, the population of said groups has experienced a 33% and a 38% drop, respectively.

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Figure 5: Graphical reprezentations of the simulation results for the male population aged 28 to 34 and 35 to 44 throughout the duration of the simulation in all three scenarios.

The population of the Male age 45 to RA group is mostly unaffected by the fertility changes, but a slight increase in the population of the age group is noticeable in scenario 3 by the end of the observed period. There is, however, a slight increase in the groups’ population during the 2031.-2037. period due to the planned increase of the retirement age. This change also accounts for the simultaneous temporary slump in the population of the Male RA and older age group, but the same group is not affected by the changes in fertility during the observed period.

It is also important to note that the size of the population of that age increases by around 35%, from 296208 to 399225, during the same period, which, in terms of its share in the total population, represents an increase from 6,91% to 9,93% in the best case scenario, and to 13,17% in the worst case scenario.

The relative increase is similar in the female population of the same age group, around 33% or, in absolute terms, from 462425 people in the beginning of the simulation to 614489 at the end of the observed period. In terms of its share in the total population, this represents an increase from a 10,79% share to a 15,28% share in the best case scenario, and to a 20,27% share in the worst case scenario. In summation, the results of the simulation suggest that the share of people in the retirement age in the total population will be in the range between 25,21% and 33,44%, depending on the scenario.

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Figure 6: Graphical reprezentations of the simulation results for the male population aged 45 to RA and RA and older throughout the duration of the simulation in all three scenarios.

## 4.3. Military dynamics simulation results

As expected, the reduction in the male and female populations between ages 18 and 27 caused a proportional decline in the recruitment pool in all three scenarios. In 2061., the model predicts its size to be between 26059 members in Scenario 1 to 108011 in Scenario 3. With the constant value of the “SHARE READY TO APPLY LOOKUP” of one percent throughout the simulation, the model predicts that the number of the active military personnel will begin declining rapidly in the year 2044. to a level well below the planned 15000 troops [24].

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Figure 7: Graphical reprezentations of the expected changes in the size of the recruitment pool and active military personel in all three scenarios.

The population drop also has an adverse effect on the total number of reserves which can be mustered in case of an emergency. Total reserves experience a severe decline, dropping from 790132 in 2011. to 323112 in 2061. in Scenario 1 or to 516420 in 2061. in Scenario 3. The graph of the “first contract” variable indicates that, after some volatility due to the planned restructuring of the age and rank composition of the Croatian military, the decline in the number of active military personnel is closely correlated to the reduction in the employment of new soldiers. The values of these important stocks and velocities are shown and compared in Table 2 below.

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Figure 8: Graphical reprezentations of the expected changes in the number of the total reserves, and the number of people signing the first active military service contract in all three scenarios.

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| Variable name | Scenario 1 | | Scenario 2 | | Scenario 3 | |
| 2011. | 2061. | 2011. | 2061. | 2011. | 2061. |
| Recruitment pool | 239600 | 26059 | 239600 | 40868 | 239600 | 108011 |
| Went to VMT | 15000 | 707 | 15000 | 796 | 15000 | 1382 |
| Soldiers | 5998 | 3215 | 5998 | 3746 | 5998 | 6735 |
| Non-commissioned officers | 5778 | 4892 | 5778 | 4892 | 5778 | 4892 |
| Commissioned officers | 3377 | 2547 | 3377 | 2547 | 3377 | 2547 |
| Active military personnel | 16490 | 10878 | 16490 | 11486 | 16490 | 14869 |
| Total reserves | 790132 | 323112 | 790132 | 356804 | 790132 | 516420 |

Table 2: The comparison of the starting and final values of relevant variables in all three scenarios.

## 5. Discussion

The structure of the model and the results of the simulation highlighted the existence of several key issues that have a significant effect on the long-term sustainability of the Croatian Armed Forces, and starting with the demographic trends that are already in effect.

Due to the currently low total fertility rate and the slightly negative migration balance, Croatia will probably experience some reduction in the population of the working age. The retirement age reform will mitigate some of the effect for a short while, but the simulation results show that, by the year 2061., this population will be reduced by 540269 people in the best case Scenario 3, and by 1033635 in the worst case Scenario 1.

And while the high fertility Scenario 3 would help to stabilize the size of the workforce in the long run, the first results in that regard would show only after 18 years. By then, the share of the workforce in the total population would drop due to the increased number of children in combination with the increase in the retirement age population. The effects of the drop are faster and more pronounced in Scenario 3, but, by the end of the simulation, the share of workforce in the total population converges to around 55% in all three scenarios.

According to [21], the increase in the retirement age population will demand a large increase in public expenditure for pensions and health services. Coupled with the smaller tax base, there is a significant possibility that some pressure will be exerted to reduce military spending, or at least not to increase it further. Due to the importance of wages to the appeal of military career [16], and the probable increase in the job market competition from the private sector [14], the military could feel a further reduction in size due to either a lack of interest or through an increased share of trained soldiers leaving the military to join the civilian workforce.

Some of the predicted negative effects could be mitigated by an increase in the flow of working-age immigrants into Croatia which would increase the size of the workforce and reduce the competition the private sector represents to the military in the job market. But while an increase in the number of immigrants could relieve the pressure exerted on the military for these reasons, it has no short-term effect on the size of the recruitment pool due to the citizenship requirements for military employment. On the other hand, emigration has both an immediate and a long-term effect on the size of the recruitment pool proportional to its volume, not to its net effect on the migratory balance , and as such represents a significant risk to the adequacy of military recruitment.

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Figure 9: Graphical reprezentations of the expected changes in the size of the workforce, as well as the share of workforce in the total population in all three scenarios.

## 6. Conclusion

Following the simulation results that show an almost linear continuation of current trends in scenarios 1 and 2, it is safe to assume that there is a higher probability that the demographic future of Croatia will follow along those lines. Although the Recruitment pool will technically be sufficiently large to accommodate the needs for recruits of the Croatian military, its success will depend mostly on its ability to remain a competitive employer in spite of the decreasing labor supply and the mounting budgetary pressures due to pension and public health expenditure growth.

The results also highlight the necessity of creating long-term plans development plans due to long-term effects of demographic changes, as well as the significant delay to the effect the changes in fertility have on the workforce. Introduction of scenario planning would assure the robustness of these long-term plans, and the use of system dynamics in their development would enable the planners to optimize the desirable effects by making use of the relevant feedback loops.

The main problem with the presented model is the relatively large number of lookups due to the lack of relevant research on which support models could be based to provide better results and create a more useful model. Considering the potential benefits of such models, the authors recommend that more research should be conducted in regards to this subject, especially in the field of external migrations and its causes. The authors also recommend increasing the use of system dynamics models as a decision support tool for policy making on all of the levels of government.

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**Abstract**

The events of 9/11 and the subsequent wars in Afghanistan and Iraq brought attention to the requirements of asymmetric and urban warfare, in addition to highlighting international terrorism as a growing threat to global security. The rapid technological advancement in the fields of electronics and communication opened new challenges to defense doctrines by introducing robotics and ‘intelligent’ weaponry to the battlefield. Introduction of sterner budgetary constraints brought the cost-effectiveness of military programs back in the eye of the public. Due to changes in the geopolitical environment, as well as the economic challenges set by the global financial crisis, there have been priority shifts in the national security strategies. In most cases, it meant reductions in manpower and additional spending, while maintaining or even improving national security through optimization of the use of available resources. In line with the global trends, Croatian military is also going through the transformation, but one that is currently being stifled by a long recession and negative demographic trends. The purpose of this article is to outline the possibilities for the usage of system dynamics models in testing the sustainability of Croatian military forces according to the size and composition. The main focus of the article is on the demographic trends and their implications on the Croatian military forces. After a brief exposition of the research done in this field so far, two models are developed in the article – a demographic model and a recruitment model of military forces. Two models were carefully tested using validation tests suitable for system dynamics modeling. After the validation, the models were merged into one integral system dynamics model of Croatian military forces. Three experiments were conducting based on the different values of fertility, and impact of demographic trends, which emerge from the different fertility level, was tested. The results of the simulation based on the use of the demographic data from the Census of 2011, as well as estimates for the data which was not accessible at the time, suggest that the Croatian military could have trouble meeting its demands for recruits in the next 20-30 years. Additional implications of the current demographic trends on the sustainability of the Croatian military forces are discussed in the end. Since the basic inputs for any organization (civilian and military alike) are labor and capital, the problem is addressed from two complementary perspectives: a demographic perspective and a financial one.